Title: Risk and Resilience Predictors of Recovery after Spinal Fusion Surgery in Adolescents

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ABSTRACT

Objective: This prospective study examined risk and resilience predictors of pain and functional recovery in the first six months after major surgery in adolescents. **Methods:** Adolescents with Adolescent Idiopathic Scoliosis undergoing spinal fusion surgery (n = 100, aged 12 to 18 years, 77% girls) completed assessments prior to surgery, and at three weeks, six weeks, and six months after surgery. Recovery trajectories in pain, health-related quality of life, and objectively registered physical activity were identified. Pre-surgical pain catastrophizing and pain intensity (risk), and psychological flexibility and postsurgical pain acceptance (resilience) were examined as predictors of recovery. **Results:** Latent growth class analyses revealed four distinct pain recovery trajectories (i.e., *Severe-Moderate* (11 %, n = 9), *Mild-No* (58%, n = 49), *Moderate-Mild* (24%, n = 20), and *Moderate-Severe* (7%, n = 6) pain trajectory), two Health-Related Quality of Life (HRQOL) recovery trajectories, two trajectories characterizing recovery in average daily physical activity at moderate-to-vigorous intensity (MVPA), and three trajectories characterizing recovery in total physical activity volume characterized by the average daily number of steps. Subsequent MANOVA analyses revealed that pre-surgical pain intensity (partial $\eta^2 = .21$, $p < .001$)and pain catastrophizing (partial $\eta^2 = .13$, $p < .01$) were both predictive of poorer recovery in HRQOL, and pain catastrophizing additionally predicted poorer pain recovery (partial $\eta^2 = .15$, $p < .05$). Psychological flexibility (partial $\eta^2 = .25$, $p < .001$) and postsurgical pain acceptance (partial $\eta^2 = .07$, $p < .05$) were predictive of more favorable recovery trajectories in HRQOL, and psychological flexibility additionally predicted more favorable recovery trajectories in postsurgical pain (partial $\eta^2 = .15$, $p < .05$). Daily MVPA trajectories were not significantly predicted by any of the hypothesized factors, while pre-surgical pain catastrophizing levels were predictive of a delayed recovery trajectory in daily amount of steps (partial $\eta^2 = .17$ $p < .01$). **Conclusions:** Pre-surgical screening could include assessment of pain intensity, pain catastrophizing, psychological flexibility, and pain acceptance to identify adolescents who are at-risk for poorer recovery. These are potentially modifiable factors that can be targeted in pre-surgical interventions to prevent poor and foster adaptive outcomes after major surgery in adolescents.

Keywords: risk, resilience, postsurgical, recovery, pain, adolescent idiopathic scoliosis

INTRODUCTION

Spinal fusion surgery is one of the most common major surgical procedures performed in youth [1] and has been associated with moderate to severe pain levels and significant impairments in daily functioning [4,14,25]. Although some levels of acute postsurgical pain are normal when recovering from such major surgery, approximately 20% of children and adolescents continue to show moderate to severe pain levels up to one year after the surgery [2]. Chronic postsurgical pain (i.e., "pain lasting for three months or longer after surgery that is not otherwise associated with pre-existing problems or postsurgical complications" [3] has attracted increasing attention within the pediatric pain literature. Interestingly, research has shown that the course of postsurgical pain recovery can differ considerably between adolescents [2]. For instance, one study showed up to five distinct trajectories in pain recovery in a sample of adolescents who underwent spinal fusion surgery [4]. Undergoing major surgery may likewise cause significant impairments in other domains of functioning beyond pain. In the first weeks following surgery most children and adolescents experience decreases in their physical and psychosocial quality of life [5], with about 10% still reporting impairments in their quality of life and daily functioning at one year after surgery [6].

Inter-individual differences in postsurgical health outcomes have motivated researchers to identify biological, psychological, and social *risk factors* that are predictive of poor recovery. Pre-surgical pain intensity and anxiety have been identified as the most important predictors of the development of chronic postsurgical pain in youth undergoing major surgery [1,2]. Although pre-surgical pain catastrophizing has been identified as an important risk factor in many adult studies[9], current pediatric studies are limited and inconclusive with some demonstrating it to predict worse pain immediate after surgery[10] and others reporting no link with pain recovery[5,8,11].

Despite the progress that has been made in identifying risk factors that predict poorer postsurgical recovery following major surgery in youth, there are still several empirical, theoretical, and methodological gaps that can be acknowledged in this area. First, the aforementioned work has largely focused on the study of postsurgical *pain* recovery, whereas relatively less attention has been paid to other domains of functioning [5–8]. One study has examined predictors of poorer recovery trajectories in *quality of life* [5], another has documented different trajectories of recovery in *physical activity* levels in the initial weeks following in- and outpatient surgery in children and adolescents [8] and one recent study has examined predictors of functional disability at one year after pediatric surgery [9]. Moreover, most studies have relied on self-report measures to assess postsurgical recovery in adolescents, although this subjective procedure is known to be prone to several biases (e.g., self-presentation, memory biases) [24]. Objective monitoring of pre- and postsurgical physical activity levels (e.g., using accelerometers) has been suggested as a useful tool to indirectly assess functional recovery in terms of re-engagement in physical activities after surgery (e.g.,[8]).

Second, most of this work has focused on examining risk factors for poorer postsurgical outcomes [1,2,4,6,11,14]. Yet the majority of children and adolescents return to pre-surgical pain and functional levels within an expected recovery time [2]. Although identifying and targeting risk factors seems critical, *protective* factors that predict normal recovery following surgery may be equally important to consider in pre-surgical prevention strategies. In the wider pain literature a risk-resilience perspective has been proposed which promotes the study of these so-called ‘resilience’ factors that may predict adaptive functioning in the presence of pain or physical complaints [15,16]. *Resilience* is defined as “effective functioning despite the exposure to stressful circumstances and/or internal distress” [16,17]. To date only one study has hinted at such a potential resilience factor for faster pain recovery after surgery, i.e., greater pain coping efficacy [14]. Another psychosocial resilience factor that may be promising in this context is psychological flexibility. *Psychological flexibility* can be described as being aware of, and open to unwanted and uncontrollable inner experiences, while still being able to act in-line with what one values in life [18,19]. It encompasses flexibility in dealing with challenges in several domains of daily life (such as those associated with recovery from surgery). Psychological flexibility and one of its subcomponents, *pain acceptance*, have been related to beneficial functional outcomes in children and adolescents who are confronted with (persistent) pain [20–23]. No prior studies have examined psychological flexibility as a predictor of pain or other health outcomes in the context of major pediatric surgery.

The current study employed a prospective design (with four time points from before surgery up to six months following surgery) to assess postsurgical recovery across several domains, from pain, and quality of life, to objectively measured daily physical activity and its predicting factors. In line with previous work, a first objective was to explore distinct trajectory patterns of postsurgical recovery in a sample of patients with adolescent idiopathic scoliosis (AIS) who underwent spinal fusion surgery. A second objective was to examine factors that were predictive of individual differences in postsurgical recovery. In addition to previous work that identified *risk factors* predictive of worse outcomes, the present study included the investigation of *resilience factors* that predict more favorable outcomes after surgery. Pre-surgical pain intensity and pain catastrophizing were examined as potential risk factors. It was hypothesized that these factors would predict poorer postsurgical pain, health-related quality of life, and physical activity recovery trajectories. Pre-surgical psychological flexibility and acceptance of postsurgical pain were examined as potential resilience factors. It was hypothesized that these factors would predict more favorable recovery in postsurgical pain, health-related quality of life, and physical activity.

METHODS

Participants

Adolescents diagnosed with adolescent idiopathic scoliosis (AIS) who were scheduled for spinal fusion surgery were screened for study eligibility. They were recruited from four orthopedic units in hospitals in Belgium (i.e., University Hospital Ghent, University Hospital Antwerp, General Hospital Saint-Jan Bruges, and University Hospital Leuven) between December 2016 and December 2018. Eligibility criteria for inclusion were (1) being aged between 12 and 18 years, (2) having an AIS diagnosis, (3) scheduled for posterior spinal fusion surgery, (4) being able to speak and read Dutch, and (5) having parental informed consent for their participation. Adolescents were considered as non-eligible if they had (1) prior spinal fusion surgery or (2) a severe comorbid neurological, developmental or another (mental) health condition. The flowchart in Figure 1 illustrates the recruitment procedure. The majority of refusals were related to concerns about expected time investment and additional mental load of participating beyond undergoing the surgery. This multi-centric study was approved by the Central Ethical Committee of Ghent University with permission of all local ethical committees to collect data at each site, and was carried out according to the guidelines for Good Clinical Practice (ICH/GCP) and the declaration of Helsinki for the protection of people who participate in clinical studies. Parental informed consent and adolescent informed assent were obtained online at the start of the study.

Procedure

This study is part of a larger longitudinal project , the Postoperative Recovery after Spinal Fusion Surgery (PR-SF) study (the protocol can be found at: https://biblio.ugent.be/publication/8578153). This study reports on adolescent questionnaire and physical activity data that were collected before (T0) and at three weeks (T1), six weeks (T2), and six months (T3) after surgery.

Between three to one week(s) prior to surgery (T0) adolescents completed questionnaires assessing sociodemographic and biomedical characteristics, predictive factors (i.e., psychological flexibility, pain catastrophizing, pre-surgical pain intensity), and baseline levels of the postsurgical outcome variables (i.e., health-related quality of life and postsurgical pain intensity). Baseline physical activity was assessed by means of a waist-worn accelerometer during seven consecutive days. At three weeks after surgery (T1) adolescents were asked to complete a questionnaire assessing postsurgical pain acceptance. Postsurgical outcome variables were assessed using the same questionnaires as at T1, T2, and T3. Postsurgical physical activity was only monitored at T1 and T2.

All data were collected at home; participation in this study did not require any additional hospital visits. Adolescents were reminded about an upcoming time point via telephone calls one week before they were scheduled start. Questionnaires were completed via an online, secured survey tool (i.e., Limesurvey, version 2.00). At each time point an e-mail containing the link and a personal token to access the surveys was sent to the adolescents. They were asked to complete the surveys within one week after receiving this e-mail; weekly reminders were sent up to three weeks after the first e-mail. All data collected after these three weeks were considered as invalid and excluded from further analyses. Accelerometers were provided to the participants during a house visit by a research assistant before surgery. Once all physical data collection moments were completed, they were asked to return the device to the research team either via the courier service or during one of their regular hospital appointments. Biomedical information was collected from the electronic medical record. All adolescents received standard pre-, peri-, and postsurgical treatment following the regular protocol in each hospital.

Participants were given the opportunity to either start their participation at T0 or drop in at a later point in time and start their participation at T1. This planned missing data design intentionally collects incomplete data from participants to reduce costs and burden for the participants and has limited effects on power or bias. In particular, we have accounted for missing data by collecting supplemental entrants following the same inclusion criteria (i.e. 'refreshment' sample) [26,27] . Adolescents who did not complete data at one time point were allowed to drop back in at a next time point after surgery. Information about drop-out and drop-in at each time point is presented in Figure 1. Ninety-two adolescents were enrolled in the study at T0, eight adolescents additionally decided to drop-in at T1. Main reasons for this delayed start (i.e., after surgery) were concerns about expected time investment and mental load of participating. Drop-out at subsequent time points was mainly related to adolescents' lack of time, loss of interest in the study, or inability of the research team to contact participants. As a retention strategy adolescents received reminders at each time point and a movie ticket at T3 if all required assessments were completed and the accelerometer was returned to the research team.

-INSERT FIGURE 1 ABOUT HERE-

Measures

Sociodemographic and Biomedical Information. Sociodemographic data such as age, sex, educational level, and ethnicity were collected by means of a short survey completed prior to surgery. Biomedical information (i.e., height, weight, Cobb Angle) and length of hospital stay were collected from the electronic medical record by a medical staff member in each hospital at three or six weeks after surgery.

Health-Related Quality of Life (T0 – T3). Health-related quality of life (HRQOL) was assessed by means of the child (8-12 years) and teen (13-18 years) versions of the Pediatric Quality of Life Inventory (PedsQL™ 4.0) [28]. The 23-item PedsQL™ contains five subscales designed to assess problems with physical, emotional, social, psychological, and school functioning. Items are rated on a five-point response scale ranging from 0 (*never*) to 4 (*almost always*). A total HRQOL score is obtained by reverse-scoring and transforming raw scores into standard scores on a 0-100 scale, and subsequently taking the mean of all item scores. Higher total scores indicate better HRQOL. Scores below the cut-off of 69.7 are used to identify adolescents that are 'at-risk' for impaired HRQOL. This cut-off score was based on a study comparing PedsQL™ total scores between samples of healthy children and children with chronic health conditions [28]. The PedsQL™ showed good psychometric properties in population and clinical samples [28,29]. In the present study Cronbach's alpha of the PedsQL™ scale (teen version) ranged between .89 and .97 across the four time points. All adolescents completed this teen version with the exception of two adolescents who completed the child version at T0 as they were under the age of 13. Cronbach's alpha for this child scale was .92.

Physical Activity (T0 – T2). At T0, T1, and T2 adolescents wore an accelerometer (i.e., ActiGraph™ (GT3X+); Pensacola, Florida) over a period of seven consecutive days to register daily physical activity. The Actigraph™ is a small, non-invasive device that is worn around the waist. Adolescents were asked to wear the device at the right side of the body during day and night and to remove it only for showering, swimming or activities that involve the risk to potentially damage the device (e.g., fighting sports). Verbal instructions on how to wear the device were given by a member of the research team during the house visit prior to the start of the study and additionally summarized on an information leaflet. Actigraph™ devices have been shown to be valid, objective measures to characterize physical activity levels in adolescents and children in the general population [30] as well as in clinical [31–33] and postsurgical settings [8]. Both physical activity at moderate-to-vigorous intensity levels

(MVPA) and number of steps (i.e., total physical activity volume) were included as indicators of physical activity recovery.

Pain Intensity (T0 – T3). The child version of the Graded Chronic Pain Scale (GCPS-C) [34,35] was used to measure both pre-surgical pain intensity (T0) and intensity of postsurgical pain at three weeks, six weeks, and six months after surgery (T1 – 3). Current, worst, and average pain intensity during the previous three weeks was rated on an 11-point numerical rating scale (0 = *no pain*, 10 = *worst possible pain*) and used to calculate a characteristic pain intensity score at each time point. Note that the time frame of the original GCPS-C was adjusted from six months to three weeks for use in this longitudinal study. Following prior work with numerical pain rating scales [36], scores ≥ 1 and < 4 were classified as *Mild Pain,* scores ≥ 4 and < 7 as *Moderate Pain*, and scores ≥ 7 as *Severe Pain*. The GCPS-C has been used as a valid measure of pain severity in primary care, chronic pain, and general population samples [37–39]. The child version has shown good psychometric properties in a general population sample [35]. Numerical rating scales have demonstrated good validity to measure acute postoperative pain levels in children and adolescent and is sensitive to measure change in pain intensity over time [40]. Cronbach's alpha of the pain intensity subscale in this study ranged between .74 and .89 across the different time points.

Pain Catastrophizing (T0). Adolescents completed the Pain Catastrophizing Scale for Children (PCS-C) [41] before surgery to measure their level of catastrophizing thoughts about pain. The PCS-C consists of 13 items that are scored on a scale from 0 (*not at all*) to 4 (*extremely*). The PCS-C yields three subscale scores: rumination (4 items), magnification (3 items), and helplessness (6 items) and a total score. Higher total scores (0-52) indicate greater catastrophizing and worrying about pain. Good psychometric qualities of the PCS-C have been shown with healthy and clinical samples [41]. In the current study a Cronbach's alpha of .97 was found for the PCS-C.

Psychological Flexibility (T0). The 17-item Avoidance and Fusion Questionnaire for Youth (AFQ-Y) [42] was used to assess adolescents' level of psychological flexibility before surgery. The AFQ-

Y was originally designed to assess psychological *inflexibility* through assessment of two core components: experiential avoidance (i.e., avoidance of negative or unwanted experiences) and cognitive fusion (i.e., being entangled with the content of one's thoughts or feelings). Items are rated on a five-point response scale from 0 (*not at all true*) to 4 (*very true*). In line with previous research [43,44], items were reverse-scored so that higher total scores (0-68) indicate a greater level of psychological *flexibility*. The AFQ-Y showed good psychometric properties in healthy and clinical samples [42,45]. Cronbach's alpha of the AFQ-Y scale was .90 in the current study.

Postsurgical Pain Acceptance (T1). Adolescents completed the Chronic Pain Acceptance Questionnaire for Adolescents (CPAQ-A) [46] at three weeks after surgery. The reason for assessing this individual factor at T1 instead of at baseline was that it was expected that not all participants would be in pain before surgery which made it only possible to measure this process after surgery when all participants would have (had) experienced some pain as a consequence of the invasive surgery. The CPAQ-A is a 20-item scale that measures acceptance of pain. Items are scored on a five-point response scale from 0 (*never true*) to 4 (*always true*). The scale contains two subscales assessing Activity-engagement (i.e., the extent to which adolescents attempt to participate in daily activities when in pain; 11 items) and Pain Willingness (i.e., the extent to which adolescents rate the goal to control their pain level as less important than other life goals; 9 items). Higher total scores (0-80) indicate greater levels of pain acceptance. The CPAQ-A has demonstrated good reliability and validity in samples of adolescents with (chronic) pain [46,47]. In the current study a Cronbach's alpha of .79 was found for the total CPAQ-A scale.

Data Preparation

Descriptive and missing data analyses (i.e., Little's MCAR test) were performed using SPSS (version 25, IBM Statistics). Normality and reliability checks were performed. ActiLife software (version 6.13.3) was used to transform and analyze raw physical activity data collected during waking hours. In short, activity counts were calculated based on the adolescent's movements within a pre-determined time period called an "epoch". In this study epochs of 15 seconds were used (as recommended for children and adolescents by [48]). If a period of 20 consecutive minutes of zero counts was encountered this was considered as non-wear time and these data were excluded from further analyses. Adolescents were asked to wear the accelerometer for at least 8 hours per day to reliably estimate their physical activity levels on that day. *Evenson* cut-points were used to interpret counts and estimate the total minutes spent in activities of moderate-to-vigorous physical activity (MVPA) and number of steps per day [48]. In this study the daily number of steps and minutes of MVPA were aggregated over the seven-day period to obtain average daily physical activity scores. Data of participants with less than 4 out of 7 registration days were considered as invalid and excluded from further analyses. The World Health Organization (WHO) recommends that all children and adolescents should participate in at least 60 minutes of MVPA on a daily basis to experience physical and psychological health benefits [49,50], data were evaluated relative to this guideline to interpret recovery patterns.

Data-analytical strategy

Pre-surgical pain intensity, pain catastrophizing, and psychological flexibility at T0, and pain acceptance at T1 were included as predictor variables. Postsurgical pain intensity, HRQOL, and physical activity (i.e., average daily MVPA and step count) were examined as outcome variables. Pearson product-moment correlations between predictors and outcomes were evaluated at each time point. Independent sample t-tests were performed to evaluate differences in key outcome variables and/or sociodemographic characteristics between those who enrolled before surgery and those who "dropped in" at T1.

Next, to answer the research questions, a data-analytical strategy described by Jung & Wickrama [51] was followed. First, to identify classes of individuals (cfr. Research Question 1), Latent Class Growth Analysis (LCGA) was performed in Mplus 7 [52]. LCGA is a person-centered approach used to examine patterns in outcomes over time (i.e., trajectories) and group individuals into classes based on similar patterns. Although part of growth mixture modeling, LCGA is distinct given that variances and covariances within each class are fixed to zero, assuming homogeneity of individual growth trajectories [51]. In the current study, trajectory classes were examined for each outcome separately from prior to surgery (T0) over three weeks (T1), to six weeks (T2) and ending at six months after surgery (T3; not for physical activity outcomes). An exploratory *class enumeration process* was followed to decide on how many classes to retain in the final model. This process started with specifying a baseline one-class model followed by estimating additional models thereby increasing the number of classes. Various fit indices were checked to compare model fit. First, lower values on the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the sample-size adjusted Bayesian Information Criterion (aBIC) indicated a better model fit (e.g., [53,54]). Second, entropy values higher than .80 indicated an adequate probability of group membership [53]. Third, the Vuong-Lo-Mendell-Rubin likelihood ratio (VLMR-LRT) and Bootstrap Likelihood Ratio test (BLRT) were used to compare models, with a significant p-value indicating a superior fit of the current *k* class compared to the *k - 1* class solution. The model estimation process was terminated if both likelihood ratio tests were insignificant, if the model did not converge or could not be identified [53,55]. The final model was chosen by (1) comparing all models' obtained fit indices, (2) plotting these fit indices to detect an "elbow" (i.e., the point from which there are only small decreases with respect to the fit index[1]) in the model fit across the class solutions [53], (3) examining whether there were sufficient (i.e., ≥ 5%) individuals in each class within the class solution, and (4) by reflecting on the theoretical meaning of each class solution. In a next step, the effect of potential predefined confounders (i.e., age, sex, and cobb angle) on the final class solution was explored. If significant, they were entered as control variables in the final model. Finally, trajectories (i.e. changes in estimated marginal means across time points) were plotted to evaluate and describe the classes for each outcome.

Next, MANOVAs were performed in SPSS to examine whether pre-surgical pain intensity, pain catastrophizing, psychological flexibility (T0) and postsurgical pain acceptance (T1) were associated to class membership (cfr. Research Question 2). Specifically, all predictors were entered as dependent variables, while class membership (for pain intensity, HRQOL, MVPA, and step count) was entered as an independent variable. Subsequently, in case of a significant multivariate effect, univariate main

[1] As it is not uncommon for these fit indices to decrease when more classes are added, an inspection of the size of decrease in the fit is recommended [53].

effects were evaluated to examine hypothesized relations between predictors and outcomes. All tests were evaluated against a 5% significance level. Additionally, a Bonferroni correction was applied to account for the potential impact of multiple testing on the results ($p \leq \alpha/15 = 0.003$). Higher levels of pre-surgical pain catastrophizing and pain intensity were expected to predict membership to the delayed recovery classes, while psychological flexibility and acceptance of postsurgical pain were expected to predict membership to the more favorable recovery classes.

Although no specific power calculation was performed for this study, a minimal sample size of 100 participants was recommended based on the results of a Monte Carlo simulation study examining the effects of sample size on model convergence, fit indices and parameter estimates in LGCM [56].

RESULTS

Sample Characteristics

The sample included 100 adolescents (M_{age} = 15.19 years (*SD* = 1.55), *range*: 12 – 18) with AIS who underwent posterior spinal fusion surgery. All sociodemographic and biomedical characteristics of the final sample are summarized in Table 1. No significant group differences were found with regard to the main outcome variables (i.e., pain intensity, HRQOL, MVPA and steps) and sociodemographic variables (i.e., age, sex, and education) between those who enrolled before surgery and those who "dropped in" at T1. Prior to surgery, 71% (*n* = 58) of the adolescents reported some pain (scores higher than 0), 57% (*n* = 41) reported moderate pain intensity levels (scores of 4 or higher). Adolescents most frequently reported back pain (41%), followed by pain in the neck (5%), joint pain (4%), headaches (3%), abdominal pain (3%), and non-surgery related injury-related wound pain (1%) as their primary pain location. Mean reported pain intensity prior to surgery was 3.42 (*SD* = 2.80) and ranged between 0 and 8.

The average missingness rate across all included variables and different time points was 21% (range 11 – 37%). On average 6 days (range 4 – 7 days) of usable physical activity data were available for further analyses. As Little's MCAR test indicated that the missing data were missing completely at random, $\chi^2(449) = 458.896$, $p = .363$, we used pairwise deletion in SPSS and Robust Full Information Maximum Likelihood (FIML) estimation in Mplus to handle the missing data.

- INSERT TABLE 1 HERE –

Hypothesis Testing

Pain trajectories. Following the decision making process described in the data analytical strategy, a four-class model controlling for Cobb Angle was chosen as the optimal one. This four-class solution yielded the most optimal fit indices and highest entropy value (Table 2 and Figure 2). Furthermore, the VLM-LRT and BLRT indicated it was better than a three-class solution and, finally, the four-class solution had the most meaningful interpretation. Exploration of potential confounders showed that the Cobb angle was significantly related to the intercepts ($b = -0.01$, $SE = 0.004$, $p < 0.001$) and slopes ($b = -0.01$, $SE = 0.001$, $p < 0.01$) of each of the four pain classes, whereas there was no effect of age and sex.

A *Severe-Moderate,* a *Mild-No,* a *Moderate-Mild,* and a *Moderate-Severe* pain class were derived based on visual inspection of the graph (Figure 3). This graph shows a small increase (± 1 point) in pain intensity from prior surgery to three weeks after surgery (T1) in all classes except for the *Severe-Moderate* pain class. The majority of the sample was classified into the *Mild-No* pain class (58%, $n = 49$); Figure 3 shows mild pain levels before surgery, which increased at three weeks and subsequently decreased at six weeks after surgery staying in the mild pain range in this class. At six months after surgery this class showed complete recovery from pain. Inspection of the graph (Figure 3) furthermore shows that adolescents in the *Moderate-Mild* pain class (24%, $n = 20$) reported moderate pain intensity levels before surgery, which increased at three weeks but continually decreased to mild pain levels at six weeks and six months after surgery. Figure 3 also demonstrates that the *Severe-Moderate* pain class (11 %, $n = 9$) evidenced a decrease in pain intensity levels at three weeks which continually decreased at T2, but remained stable after that and still showed moderate pain intensity levels at T3. Finally, the *Moderate-Severe* pain class (7%, $n = 6$) consistently reported moderate to severe pain intensity levels (i.e., scores ranging between 5 and 7) at every time point; Figure 3 shows a small decrease from three weeks to six weeks but increased levels at six months in this class. Pain intensity levels in this group were observed to be higher at six months than those reported prior the surgery and close to the severe pain cut-off.

Results of the MANOVA showed a significant multivariate relation between the four identified pain trajectories and baseline scores of pain catastrophizing and pain intensity (risk), and psychological flexibility and pain acceptance (resilience), Wilks' $\lambda = .745$, $F(9, 138.874) = 1.989$, $p = 0.05$, partial $\eta^2 = .09$. More specifically, univariate main effects indicated that class membership was only significantly related to baseline pain catastrophizing and psychological flexibility (Table 3). Pairwise comparisons of estimated marginal means showed that baseline pain catastrophizing was significantly higher in the *Severe-Moderate* pain class than in the *Moderate-Severe* ($p = 0.019$) and the *Mild-No* pain class ($p = 0.019$). Furthermore, baseline psychological flexibility levels were higher in the *Mild – No* pain class as compared to the *Moderate-Mild* ($p = 0.020$) and the *Moderate-Severe* pain class ($p = 0.015$) (Table 3). Our hypotheses were thus partly confirmed: pain catastrophizing predicted membership to worse pain recovery trajectories while psychological flexibility predicted more favorable pain recovery.

Health-related Quality of Life trajectories. Following the same decision strategy a two-class solution was chosen as the most optimal one (Table 2 and Figure 2). This two-class solution had the highest entropy, the VLM-LRT indicated it to be better than the one-class solution and it had the most meaningful interpretation. Age, sex, and Cobb angle were not associated with the intercept and/or slope of the classes. The final plot of HRQOL trajectories is shown in Figure 3. The *At-Risk* class (32%, $n = 32$) describes a group of adolescents who were at risk for impaired HRQOL (i.e., with HRQOL below the at-risk cut-off of 69.70 [57]) before surgery. Visual inspection of the graph shows a decrease in HRQOL at T1 in this group. Although HRQOL continually improved from T1 to T2, and from T2 to T3, this group still showed "at-risk" HRQOL levels at six months after surgery, basically reaching similar HRQOL level as before surgery. Figure 3 furthermore shows that the *Resilient* class (68 %, $n = 65$) started at healthy levels of HRQOL before surgery (i.e., above the at-risk cut off), which also decreased at three weeks (T1) after the surgery. Similar to the other class, the trajectory graph shows continual improvements in HRQOL levels at six weeks and six months after surgery in this group, returning to pre-surgical "healthy" HRQOL levels at six months.

Results of the MANOVA including all variables show a significant multivariate effect of class membership, Wilks' $\lambda = .630$, $F\,(4,66) = 9.681$, $p < .001$, partial $\eta^2 = .37$. Subsequent univariate analyses indicated significant main effects of class membership on pre-surgical pain intensity, pain catastrophizing, psychological flexibility, and postsurgical pain acceptance levels (Table 3). Pairwise comparison of estimated marginal means showed that pre-surgical pain intensity and pain catastrophizing were lower, and psychological flexibility and postsurgical pain acceptance were higher in the *Resilient* class as compared to the *At-Risk* class (Table 3). This supports the hypotheses that pre-surgical pain intensity and pain catastrophizing are related to delayed postsurgical recovery in HRQOL, and that psychological flexibility and pain acceptance are associated with a more favorable recovery in HRQOL.

Physical activity trajectories.

MVPA trajectories. Based on the decision strategy resulted a two-class solution was chosen as the most optimal one. Fit indices showed smaller decreases after both the two- and three-class solutions (Figure 2), BLRT also indicated that these class solutions were a better fit, and entropy values were only found to be adequate (>.80) for the three-class solution (Table 2). Yet, the two-class solution was retained because of its more favorable theoretical meaning and because the potential third class included less than 5% of the sample. Age, sex, and Cobb angle were no significant confounders of the intercepts and/or slopes of the final two trajectory classes.

Figure 3 shows that there was only a small difference between the trajectory classes in average daily minutes MVPA prior to surgery (i.e., 33.71 vs. 29.88 minutes), which is in both classes below the healthy cut-off of 60 minutes of MVPA on a daily basis for youth (as recommended by the World Health Organization (2011)). Further visual inspection of the trajectory graph of the *Low MVPA* class (11%, $n = 12$) shows a small decrease in average daily minutes of MVPA at three weeks, which seem to improve in the direction of pre-surgical levels at six weeks after surgery. The trajectory graph of the *Very Low MVPA* class (89%, $n = 78$) showed a bigger decrease to less than 10 average daily minutes of MVPA at three weeks surgery, which showed only small increases at six weeks after surgery.

MANOVA results show no significant multivariate effect of class membership on the hypothesized risk and resilience predictors, Wilks' λ = .964, F (4,61) = .562, p = 0.691, partial η^2 = .04. Further inspection of univariate main effects similarly showed no significant differences between the classes in terms of pre-surgical pain intensity, pain catastrophizing, psychological flexibility, or pain acceptance (Table 3). In contrast to what was hypothesized, these predictors were not associated with membership to the *Low* or *Very Low MVPA* class.

Steps trajectories. A three-class solution, controlling for baseline age, was retained as the most optimal and meaningful solution based on visual inspection of decreases in fit indices (Figure 2), and the BLRT, which showed a better fit for the three- as compared to the two-class solution (Table 2). Baseline age significantly affected intercept and slopes of two classes and were added to the final three-class model (Table 2).

The graph in Figure 3 was used to interpret and label each of the classes. All three classes showed a significant decrease in average daily step count at three weeks after surgery (T1) and an increase from three to six weeks (T2). The classes differ in baseline levels of step count and following recovery trajectory. Visual inspection of the graph shows a *Declined Steps* class with the majority of participants (48%, n = 37), characterized by the highest baseline level of steps and a steep decrease at T1 and T2 with the number of steps still being significantly lower than baseline levels at T2. Furthermore, two "resilient" classes are derived, showing a less steep decrease in average daily steps after surgery and total number of steps that are not significantly different from baseline at T2 (= recovery). The *Resilient Low Steps* class (13%; n = 10) starts at the lowest number of steps before surgery, while the *Resilient High Steps* class (39%, n = 29) starts at a higher number of steps at baseline.

MANOVA results showed a significant multivariate effect of class membership on all included risk and resilience variables, Wilks' λ = .768, F (8, 120) = 2.119, p = 0.039, partial η^2 = .12. Subsequent univariate analyses indicated one significant main effect of class membership on baseline pain catastrophizing levels but not on all other variables (Table 3). Pairwise comparison of estimated marginal means showed that pain catastrophizing levels were significantly higher in the *Declined Steps* class as compare to the *Resilient High Steps* class (Table 3). Results only give partial support for our hypotheses, i.e. pain catastrophizing levels might increase the risk for delayed recovery in physical activity levels but pain intensity, psychological flexibility and pain acceptance were no significant predictors.

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DISCUSSION

Using a prospective longitudinal design, the general aim of this study was to examine recovery trajectories in pain, HRQOL, physical activity levels after spinal fusion surgery in adolescents with AIS and identify risk (i.e., pre-surgical pain intensity and pain catastrophizing) and resilience (i.e., psychological flexibility and postsurgical pain acceptance) predictors of the different recovery trajectories.

Recovery trajectories following spinal fusion surgery

Consistent with previous work [2,4,8,59], it was found that the largest group of adolescents reported increased pain intensity levels in the first three weeks after surgery which continually decreased to low to no pain at six months post-surgery. However, three other (smaller) subgroups which showed worse pain recovery trajectories were also identified. In line with previous work these delayed recovery groups consistently showed higher pain intensity levels over the course of six months as compared to the first group [2,8,60]. Our *Moderate-Severe Pain* group can be compared to a similar worse pain recovery group in a longitudinal study by Sieberg et al. [4] that examined long-term pain trajectories up to five years after spinal fusion surgery. Different from this previous study[4], two novel delayed pain recovery trajectories emerged in our work. Both groups followed a similar pain recovery course as the majority of our sample but adolescents in these groups already reported higher pain intensity levels prior to surgery. Adolescents in the *Moderate-Mild* and the *Severe-Moderate Pain* groups respectively reported moderate/severe pain levels before surgery which continually decreased to mild/moderate pain levels at six months after surgery.

Given that recovery was only examined in the first six months after surgery it could not be analyzed if pain also eventually disappeared at later times. Although spinal fusion surgery is primarily executed to correct the spinal curvature and not to resolve pain [1], our findings suggest that at least some of the pain experienced prior to surgery was resolved by the surgery. However, this idea remains speculative as it was not possible to identify whether pain experienced after surgery was caused by the surgery itself or other (pre-surgical) factors based on these findings. In recent years, the importance of studying and effectively treating chronic postsurgical pain in children and adolescents has been emphasized [5]. The current study highlights distinct trajectories in pain recovery after spinal fusion surgery in adolescents and showed that a subgroup reported moderate to severe chronic pain levels at six months after surgery. These numbers are in line with what is generally found in terms of adolescent pain recovery across different types of major surgery [5].

Whereas previous work mainly focused on the study of postsurgical pain recovery and the development of chronic pain, we also examined recovery trajectories in HRQOL (i.e., psychosocial and physical) and physical activity.

Two HRQOL groups emerged that both showed a significant decline in HRQOL in the acute period after surgery. Similar acute decreases in HRQOL were reported in other studies across different surgical procedures [7,59]. The critical difference between the two groups was that they already showed significantly different HRQOL levels before surgery. The largest *Resilient* group showed similar average HRQOL levels before surgery as compared to a normative sample of healthy adolescents [57]. This group only reported significant impairments in HRQOL at three weeks after surgery, but bounced back to healthy HRQOL levels at six months after surgery. The smaller *At-Risk* group already showed impaired HRQOL levels before surgery when compared to the same healthy norm group. This group continued to report impaired HRQOL levels across the entire postsurgical period. The few studies that have documented long-term HRQOL outcomes after major spinal surgery suggest that HRQOL should be completely restored to healthy levels at one and two year follow-up [8,61]. Our results might point to the potential existence of a subgroup of adolescents with AIS that may be at risk for long-term impaired HRQOL after spinal fusion surgery, although this should be further examined in a study including long-term assessments beyond six months.

Finally, postsurgical recovery in physical activity was operationalized by average daily physical activity at moderate-to-vigorous intensity levels (MVPA) and number of steps. With an average of about 30 minutes of MVPA per day before surgery, none of the adolescents in this sample managed to achieve the recommended guideline of at least 60 minutes [58]. Research suggests that only 9-25% of Belgian youth actually reaches the recommended guideline [62]. Furthermore, girls and older children generally show lower compliance to these physical activity recommendations [63]. This might partly explain the poor levels that were observed in our predominantly female and adolescent sample. Potentially, prevalence rates are even lower in this sample of adolescents with AIS because of their health condition. Two MVPA classes emerged that did not differ in the average daily amount of time doing moderate to vigorous physical activities before surgery. Yet, the two classes clearly showed a distinct trajectory in physical activity recovery in the first six months after spinal fusion surgery. While the largest *Very Low MVPA* class showed a decrease to less than 5 minutes MVPA per day at three weeks after surgery which slightly increased to 10 minutes at six weeks after surgery, the other, smaller, *Low MVPA* class showed smaller decreases at three weeks which were already restored to pre-surgical levels (i.e. 30 minutes) at six weeks after surgery. Although not many other studies have examined adolescent physical activity in a postsurgical context, the findings of the present study resemble with what was found in a recent longitudinal study that also showed significant declines in the average amount of daily MVPA in the first weeks after inpatient surgery [13]. Other, cross-sectional, studies similarly demonstrated that adolescents' level of MVPA was still at 50% of the recommended guideline at one to two years after other types of major surgery [64,65]. Orthopedic surgeons generally advice their patients to avoid bicycle riding and swimming in the first six months after spinal fusion surgery. Given that these activities are typically performed at moderate-to-vigorous intensity, this might partly explain why such low levels are observed in this sample. Therefore we additionally examined the average number of daily steps as an indicator of post-surgical changes in total physical activity levels (independent from intensity levels). Here, three distinct classes were identified, indeed showing greater variation in total physical activity levels than when only looked at MVPA. The largest group showed a steep decrease in the average daily amount of steps from baseline to three weeks after surgery which was not yet restored to baseline levels at six weeks after surgery. Two other "resilient" groups also experienced a decrease in the number of average daily steps at three weeks after surgery, but these readily recovered to pre-surgical levels at six weeks after surgery. These findings show the importance of exploring different physical activity indicators after surgery as recovery patterns may differ depending on the intensity level or indicator chosen.

Pre-surgical risk and resilience predictors of recovery trajectories

Although previous work is inconclusive about the predictive value of biomedical variables for postsurgical pain recovery after major surgery [1,5,60], scoliosis severity (i.e., Cobb angle) was predictive of pain recovery in this study. Unlike previous work[1], we observed that more severe curvatures were associated with more favorable pain recovery trajectories. Potentially, another (unmeasured) variable may have confounded the positive association between the Cobb angle and membership to these more adaptive pain recovery trajectories.

We found that higher *pre-surgical pain intensity* levels were predictive of delayed recovery in HRQOL after surgery, yet these did not predict postsurgical physical activity levels. Although pre-surgical pain intensity could not be examined as a predictor of the different postsurgical pain trajectories (because it was included as the starting point), it was observed that the delayed pain recovery groups reported higher pain intensity levels before surgery compared to the more favorable pain recovery groups. This supports findings from earlier work showing that pre-surgical pain intensity is an important risk factor for worse recovery in pain [1,5] and HRQOL [7] after major surgery in adolescents. In addition, *catastrophizing about pain before surgery* was found as another risk factor for delayed recovery in pain intensity, HRQOL, and total number of steps following surgery. Although previous pediatric studies showed no consistent relation between pre-surgical pain catastrophizing and pain recovery after major surgery [5,11], our findings correspond with adult studies and theoretical models (e.g. Fear-Avoidance Model of pain [66,67]) which identified pain catastrophizing as an important predictor of chronic (postsurgical) pain. Besides, our study was one of the first to show that pre-surgical pain catastrophizing levels also predict less favorable recovery in other outcomes such as HRQOL and daily amount of steps in adolescents after surgery.

Furthermore, as expected, higher levels of *psychological flexibility prior to surgery* and *acceptance of postsurgical pain* at three weeks after surgery were predictive of more favorable recovery in HRQOL. Higher levels of psychological flexibility were also predictive of more favorable pain recovery. Unexpectedly, psychological flexibility and acceptance of postsurgical pain did not predict recovery in physical activity following surgery. As a response to the predominant focus of pain research on identifying and targeting risk factors for worse pain-related functioning [17], a growing number of studies have put forward psychological flexibility and pain acceptance as potential resilience factors that predict adaptive functioning in the presence of pain [24,25,44,47,68,69]. Importantly, the predominant goal of promoting psychological flexibility and pain acceptance is maintaining a valued life despite the pain or physical complaints and *not* reduction in these physical outcomes [20]. Our findings are in line with this idea showing its predictive value for (more favorable) HRQOL but also for pain outcomes following surgery. Lower experienced pain intensity levels might be a secondary consequence of generally improved well-being, although this is a post-hoc speculation which needs further examination.

Strengths and Limitations

The current study had several strengths. In contrast to previous work recovery trajectories in functional outcomes and physical activity levels were examined in addition to pain outcomes. It was also one of the first studies in this domain to *objectively* assess physical activity trajectories up to six months after surgery (also see [13]). Furthermore, and most importantly, it was the first to focus on potential resilience factors and demonstrate its adaptive effects of in a surgical context.,

Despite these strengths, our findings should be interpreted in the light of several limitations. First, our sample size was quite small. It may be that in larger samples more meaningful classes with a substantial number of adolescents could be identified. Although we applied the “common practice” cut-off value of 5% in order to evaluate if a class was meaningfulness, some classes only consist of 10 or less people. These classes are useful to provide a first look on potential recovery patterns but first require replication in larger samples before further interpretations can be made. Moreover, due to this limited sample size, performance of more complex trajectory analyses was restricted. One reason for the relatively small sample size might be that we included a very specific clinical population. Over the course of one year, only a limited number of adolescents with AIS undergo scoliosis surgery because this is often a final treatment option for the more severe cases. Furthermore, adolescents with comorbidities were excluded. We have tried to meet this recruitment challenge by maximizing our reach potential through the involvement of the four main (university) hospitals in Flanders who perform scoliosis surgery. Furthermore, an average of 21% of data were missing across variables and time points. This limitation may be mitigated by the fact that drop-out is a common challenge in longitudinal studies with attrition rates ranging between 30 – 70% in other studies with a longitudinal design [70], the fact that data was not systematically missing, and that we used Robust Full Information Maximum Likelihood estimation to handling this missingness. Another limitation was that other potentially important predictors of postsurgical functioning were not examined because this would lead to too complex models to estimate given the small sample size. Next, we were restricted by the availability of validated measures to assess the variables of interest in this context of (sub)-acute postsurgical pain. The GCPS assesses current pain levels but also requires a recall of average and worst pain over a period of 3 weeks, which may be problematic for youth experiencing (sub-)acute pain. Also, the CPAQ was originally developed to assess acceptance of chronic pain and we were one of the first to use this in a subacute pain context. Furthermore, this study may have been exposed to some threats to generalizability of the results to the entire population of youth undergoing major surgery. The sample mainly consisted of girls and was focused on one surgical procedure type. As such, our findings may not generalize to boys undergoing spinal fusion surgery or to recovery from other surgical procedures. Some level of self-selection bias may have occurred in that sense that our study may have attracted relatively more resilient adolescents than those at greater risk for worse recovery (and who might need the most help). Indeed, about 25% of the patients who were approached for this study declined participation because of the expected high mental load of participation. Finally, it may be that different trajectories and predictors may emerge if assessments at later points in time after surgery are included.

Future directions

Future research could investigate more complex models using bigger samples (n > 100). For instance, it may be examined how recovery in pain, quality of life and physical activity co-vary over time by adding them into one big model. Future work could additionally investigate the role of the social context. For instance, it has previously been shown that parental behavior may have an important impact on adolescent recovery after major surgery [5,7,8,71]. Also, the influence of peers and/or health care providers could be further explored as these may have a critical influence on the functioning of adolescents who experience (chronic) pain [12,72,73]. Furthermore, there may be other psychosocial resilience factors that could predict *adaptive* recovery after major surgery. We are aware of one previous study that found effective pain coping to be such a protective factor for recovery after spinal fusion surgery [2], but there remains a wide range of other factors to be explored [17]. Finally, future work could consider to use alternative pain measures that assess (sub-acute) pain levels, validated direct measures of psychological flexibility (which is currently not available, to the best of our knowledge), and further explore the ability to assess acceptance of (sub-)acute pain. In general, replication of our findings in larger samples is required before making further conclusions about their predictive value for post-surgical pain recovery in adolescents undergoing major surgery.

Clinical Implications

If replicated, our findings may inform clinicians about the importance of a multidimensional recovery assessment (including pain, quality of life, and physical activity levels) after major surgery in children and adolescents, and to monitor changes in each domain for at least six months after surgery (and potentially longer; see [4,5]). Our findings also suggest that a screening of psychological risk and resilience factors should preferably be conducted before surgery in order to target them, prevent worse outcomes, and stimulate adaptive recovery. This need for pre-surgical psychosocial interventions has already been expressed by parents of children undergoing surgery [12]. It may be suggested that such interventions could be conducted in adolescents who are at risk for maladaptive outcomes and could involve aspects of pain acceptance and psychological flexibility. These concepts are central to Acceptance and Commitment Therapy (ACT), a cognitive-behavioral therapy that enhances flexibility in dealing with negative or unwanted experiences and continued engagement in valued activities despite this adversity. One study in adults undergoing orthopedic surgery gave preliminary evidence for the efficacy of a one-day pre-surgical ACT intervention in preventing worse recovery [74]. Future research could examine the effectiveness of a brief ACT intervention to promote adaptive functioning in adolescents as well. Finally, our study supports that accelerometers are a useful tool to objectively assess physical activity in adolescents who undergo major surgery (see also [13,64]). Although adolescents in this study did not meet the recommended physical activity levels, achieving this is associated with beneficial social, mental, and physical health outcomes [63]. Health care providers could use accelerometers to stimulate physical activity before and after surgery [75].

Conclusion

This study identified distinct postsurgical pain, HRQOL, and physical activity trajectories in a sample of adolescents with AIS undergoing spinal fusion surgery. Pre-surgical pain intensity and pain catastrophizing increased the risk for lower HRQOL, while pain catastrophizing additionally predicted lower levels of pain intensity and average daily number of steps after surgery. Psychological flexibility before surgery and acceptance of postsurgical pain were predictive of adaptive HRQOL outcomes, and psychological flexibility additionally predicted more favorable recovery in pain after surgery. Average daily MVPA was not predicted by any of these risk or resilience predictors. Future work could explore additional risk and resilience predictors of both pain and functional outcomes after major surgery. These findings could inform targeted screening and intervention prior to surgery to prevent poor and foster adaptive recovery in adolescents.

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TABLES AND FIGURES

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Table 2. Parameters of fit for latent class growth analysis for recovery classes in all outcomes

Table 3. Univariate main effects and pairwise comparison of means to examine relations between class membership and hypothesized risk and resilience variables

Figure 1. Flow-chart of recruitment, drop-in, and drop-out of participants during the study.

Note. Participants were given the opportunity to start their participation after surgery (T1), these are referred to as "drop-in (new)" participants. Participants were also given the opportunity to re-start their participation after missing one or more measurement moments, these are referred to as "drop-back-in (old)" participants.

Figure 2. Plot of fit indices for all outcomes.

Note. BIC = Bayesian Information Criterion; AIC = Akaike Information Criterion; aBIC = adjusted Bayesian Information Criterion.

Figure 3. Plots of final recovery trajectories.

Note. MVPA= Moderate-to-Vigorous Physical Activity; T0 = 3-1 weeks before surgery;

S = Spinal Fusion Surgery; T1 = 3 weeks after surgery; T2 = 6 weeks after surgery; T3 = 6 months after surgery

Table 1. Sample characteristics.

Characteristic	**M (± SD) or N**
Age	15.19 (± 1.56)
Sex	
Female	77
Male	23
Race	
Caucasian	99
Asian	1
Educational level	
Primary School	2
High School	98
Medical variables	
Cobb angle (degrees)	52.19 *(± 10.65)*
Height (cm)	165.88 *(± 8.04)*
Weight (kg)	55.05 *(± 10.33)*
Length of hospital stay	
< 7 days	53
7 – 14 days	31
15 – 21 days	2
Missing info	*14*

Table 2. Parameters of fit for latent class growth analysis for recovery classes in all outcomes

Outcome	Class	AIC	BIC	aBIC	Entropy	VLMR-LRT *p*	BLRT *p*
Pain	1	1428.00	1443.39	1424.45	-	-	-
	2	1330.69	1353.77	1325.36	.90	.001	.000
	3	1308.16	1338.94	1301.05	.88	.347	.000
	4	**1276.48**	**1314.94**	**1267.58**	**.92**	**.021**	**.000**
	5	1264.84	1311.00	1254.17	.90	.178	.000
	6*	1262.19	1316.04	1249.74	.90	.738	.207
	4[a]	**1137.75**	**1186.37**	**1123.28**	**.95**	**.031**	**.000**
HRQOL	1	2867.14	2882.59	2863.64	-	-	-
	2	**2779.16**	**2802.33**	**2773.91**	**.81**	**.000**	**.000**
	3	2765.08	2795.98	2758.09	.81	.206	.000
	4	2752.25	2790.87	2743.50	.76	.234	.000
	5*	2756.64	2802.98	2746.14	.86	.279	.667
MVPA	1	1584.90	1597.28	1581.51	-	-	-
	2	**1564.99**	**1584.81**	**1559.57**	**.72**	**.141**	**.000**
	3	1554.20	1581.45	1546.74	.81	.236	.000
	4*	1553.15	1587.83	1543.65	.85	.077	.113
Steps	1	1088.29	1100.67	1084.90	-	-	-
	2	1088.98	1108.80	1083.56	.79	.113	.667
	3	**1085.87**	**1113.12**	**1078.41**	**.62**	**.433**	**.050**
	3[b]	**963.93**	**998.70**	**951.42**	**.66**	**.195**	**.078**
	4*	1087.69	1122.38	1078.20	.70	.682	.667

Notes. **bold** numbers indicate the output of the final class solution; [a] final class solution controlling for Cobb angle at baseline; [b] controlling for age at baseline; AIC = Akaike information criterion; BIC = Bayesian information criterion; aBIC = adjusted BIC; VLMR-LRT = Vuong-Lo-Mendell-Rubin likelihood test; BLRT = Bootstrap likelihood ratio test; HRQOL = Health-Related Quality Of Life; MVPA = Moderate-to-Vigorous Physical Activity. *Model specification was terminated when both VLM-LRT and BLRT were insignificant.

Table 3. Univariate main effects to examine relations between class membership and hypothesized risk and resilience variables

				Pain (4-class)			
	class	M *(SD)*	*F*	*df (hyp)*	*df (error)*	*p*	partial η^2
Pain Catastrophizing (T0)	1	25.29 *(3.92)*[a]	3.50	3	376.93	.021*[†]	.15
	2	14.92 *(1.73)*[b]					
	3	19.57 *(2.77)*[a,b]					
	4	26.00 *(4.24)*[a]					
Psychological Flexibility (T0)	1	45.86 *(3.80)*[a,b]	1086.23	3	362.07	.019*	.15
	2	52.31 *(1.68)*[a]					
	3	44.71 *(2.69)*[b]					
	4	41.17 *(4.11)*[b]					
Pain Acceptance (T1)	1	41.57 *(3.76)*[a,b]	601.79	3	200.60	.119	.09
	2	46.14 *(1.66)*[a]					
	3	40.86 *(2.66)*[a,b]					
	4	37.33 *(4.06)*[b]					
				HRQOL (2-class)			
	class	M *(SD)*	*F*	*df (hyp)*	*df (error)*	*p*	partial η^2
Pain Intensity (T0)	1	5.17 *(2.29)*	18.55	1	120.22	.000***	.21
	2	2.49 *(2.69)*					
Pain Catastrophizing (T0)	1	22.70 *(10.31)*	9.94	1	1119.87	.002**	.13
	2	14.52 *(10.80)*					
Psychological Flexibility (T0)	1	42.00 *(8.93)*	22.66	1	2041.39	.000***	.25
	2	53.05 *(9.81)*					
Pain Acceptance (T1)	1	40.73 *(10.59)*	5.19	1	530.29	.026*[†]	.07
	2	46.00 *(9.80)*					
				MVPA (2-class)			
	class	M *(SD)*	*F*	*df (hyp)*	*df (error)*	*p*	partial η^2
Pain Intensity (T0)	1	2.73 *(3.47)*	1.20	1	9.72	.277	.02
	2	3.80 *(2.73)*					
Pain Catastrophizing (T0)	1	13.30 *(10.92)*	2.14	1	279.14	.148	.03
	2	19.04 *(11.48)*					
Psychological Flexibility (T0)	1	52.30 *(10.85)*	1.06	1	129.53	.308	.02
	2	48.39 *(11.11)*					
Pain Acceptance (T1)	1	43.80 *(9.21)*	0.03	1	2.91	.872	.00
	2	43.21 *(10.73)*					
				Steps (3-class)			
	class	M *(SD)*	*F*	*df (hyp)*	*df (error)*	*p*	partial η^2
Pain Intensity (T0)	1	4.60 *(0.88)*	2.22	2	34.68	.117	.07
	2	2.77 *(0.55)*					
	3	4.08 *(0.51)*					
Pain Catastrophizing (T0)	1	20.00 *(3.36)*[a,b]	6.56	2	1483.65	.003**	.17
	2	12.39 *(2.09)*[a]					
	3	22.57 *(1.94)*[b]					
Psychological Flexibility (T0)	1	50.20 *(3.53)*	0.49	2	121.27	.617	.02
	2	50.23 *(2.19)*					
	3	47.50 *(2.04)*					
Pain Acceptance (T1)	1	44.10 *(3.35)*	0.06	2	13.53	.942	.00
	2	42.80 *(2.08)*					
	3	43.47 *(1.94)*					

[a] Estimated marginal means with a different superscript are significantly different ($p < .05$); *$p < .05$, ** $p < .01$, *** $p < .001$; [†] loss of significance when applying Bonferroni correction to account for multiple testing ($p \leq \alpha/15 = 0.003$); Pain classes (1 = *Severe-Moderate*, 2 = *Mild – No*, 3 = *Moderate – Mild*, 4 = *Moderate – Severe*; HRQOL classes (1 = *At-risk*, 2 = *Resilient*; MVPA classes (1 = *Low MVPA*, 2 = *Very Low MVPA*), Steps classes (1 = *Resilient Low Steps*, 2 = *Resilient High Steps*, 3 = *Declined Steps*). HRQOL = Health-Related Quality Of Life, MVPA = Moderate-to-Vigorous Physical Activity. T0 = before surgery; T1 = 3 weeks after surgery

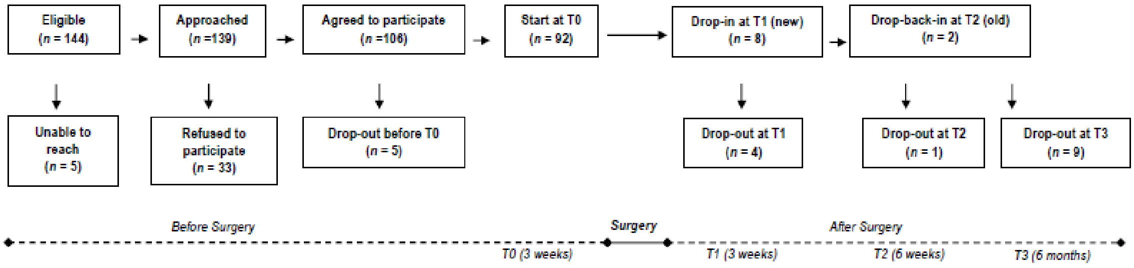


Figure 1. Flow-chart of recruitment, drop-in, and drop-out of participants during the study.
Note. Participants were given the opportunity to start their participation after surgery (T1), these are referred to as "drop-in (new)" participants. Participants were also given the opportunity to re-start their participation after missing one or more measurement moments, these are referred to as "drop-back-in (old)" participants.

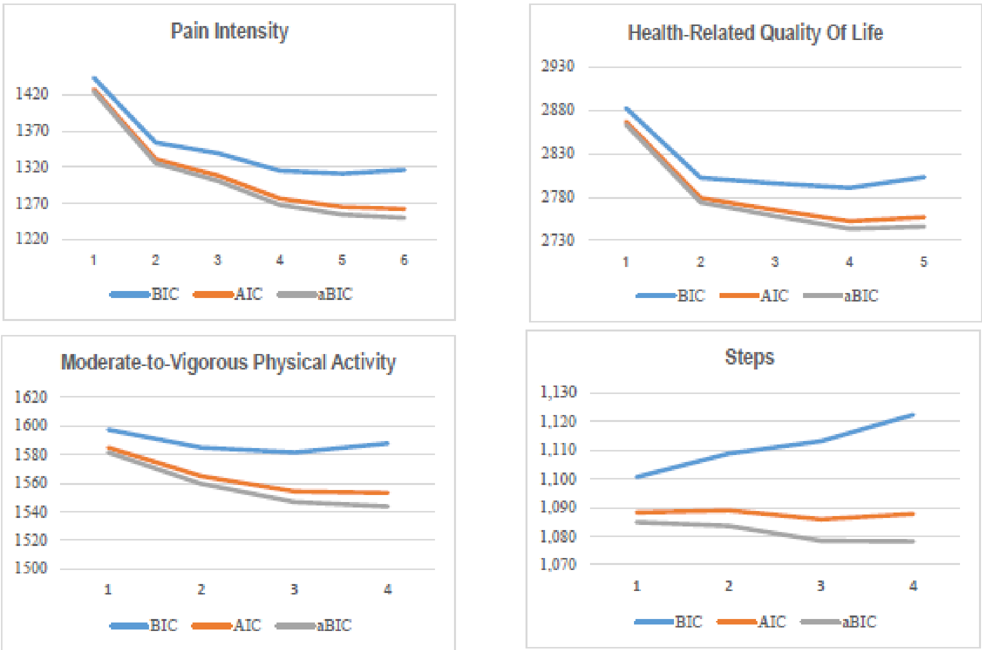
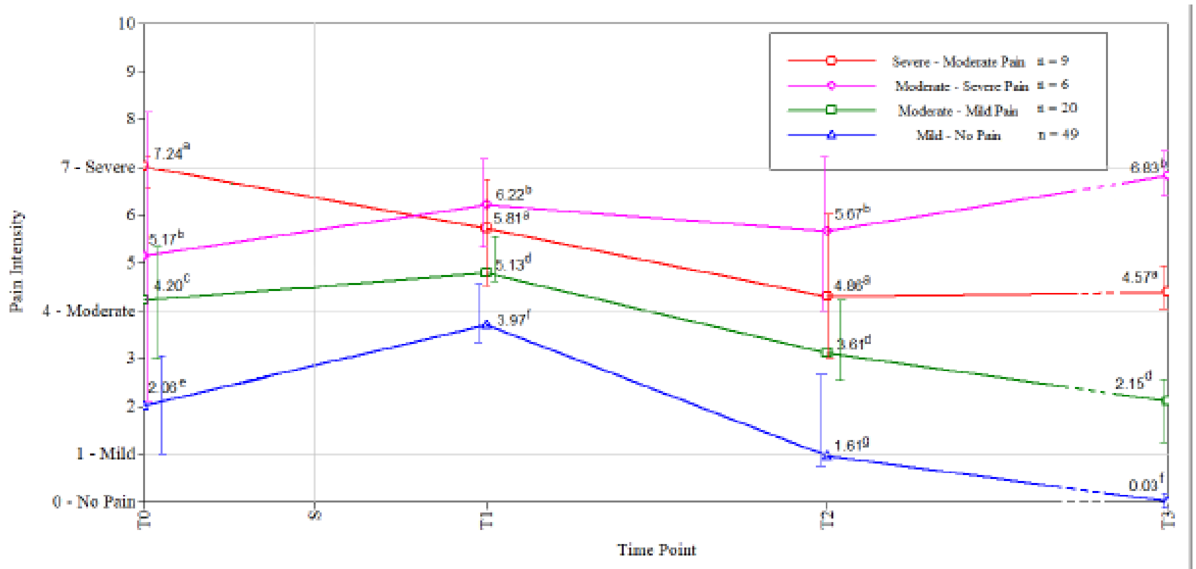
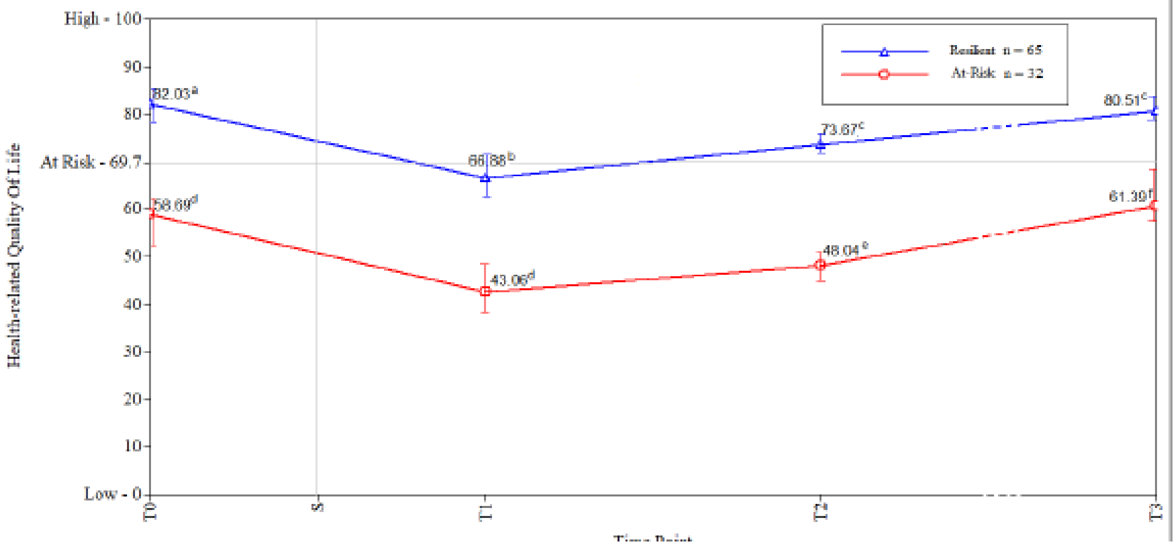
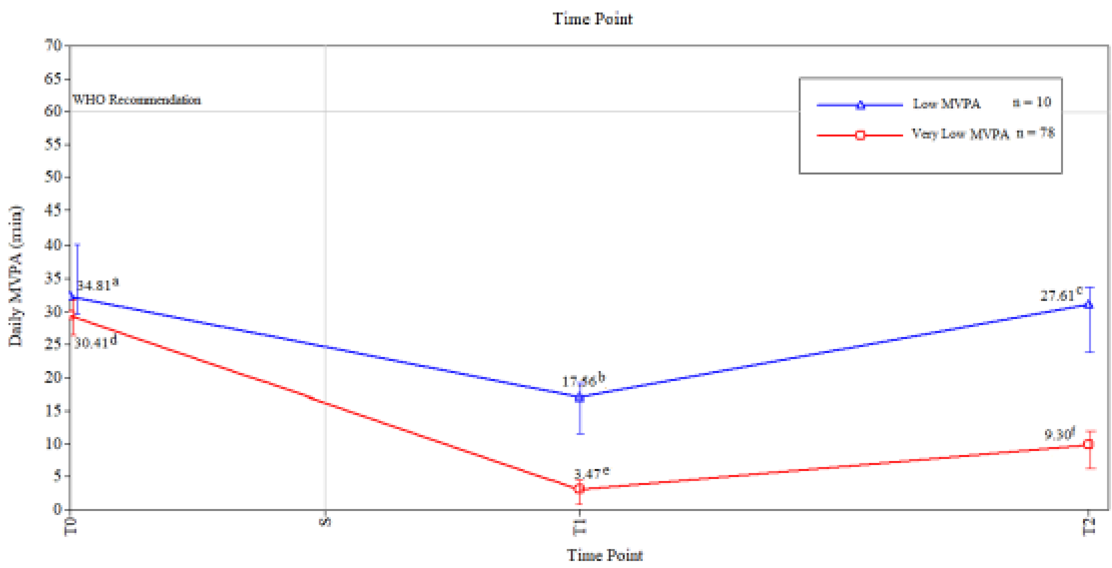


Figure 2. Plot of fit indices for all outcomes.
Note. BIC = Bayesian Information Criterion; AIC = Akaike Information Criterion; aBIC = adjusted Bayesian Information Criterion.


Pain Intensity
10
9
8
7 - Severe
6
5
4 - Moderate
3
2
1 - Mild
0 - No Pain
T0
S
T1
T2
T3
Time Point
Severe - Moderate Pain n = 9
Moderate - Severe Pain n = 6
Moderate - Mild Pain n = 20
Mild - No Pain n = 49
7.24a
5.17b
4.20c
2.06e
6.22b
5.81a
5.13d
3.97f
5.67b
4.86a
3.61d
1.61g
6.83b
4.57a
2.15d
0.03f


Health-related Quality Of Life
High - 100
90
80
At Risk - 69.7
60
50
40
30
20
10
Low - 0
T0
S
T1
T2
T3
Resilient n = 65
At-Risk n = 32
82.03a
66.88b
73.67c
80.51c
58.69d
43.06d
48.04e
61.39f


Time Point
Daily MVPA (min)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
WHO Recommendation
Low MVPA n = 10
Very Low MVPA n = 78
34.81a
30.41d
17.66b
3.47e
27.61c
9.30f
T0
S
T1
T2
Time Point

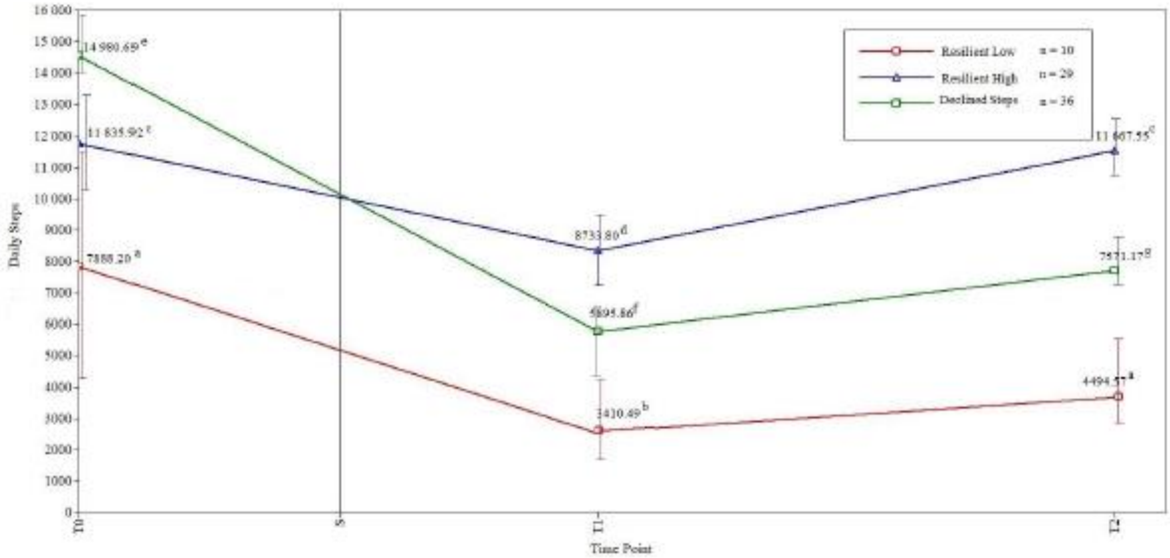


Figure 3. Plots of final recovery trajectories with estimated marginal means and 95% confidence intervals.
Note. MVPA= Moderate-to-Vigorous Physical Activity; T0 = 3-1 weeks before surgery; S = Spinal Fusion Surgery; T1 = 3 weeks after surgery; T2 = 6 weeks after surgery; T3 = 6 months after surgery